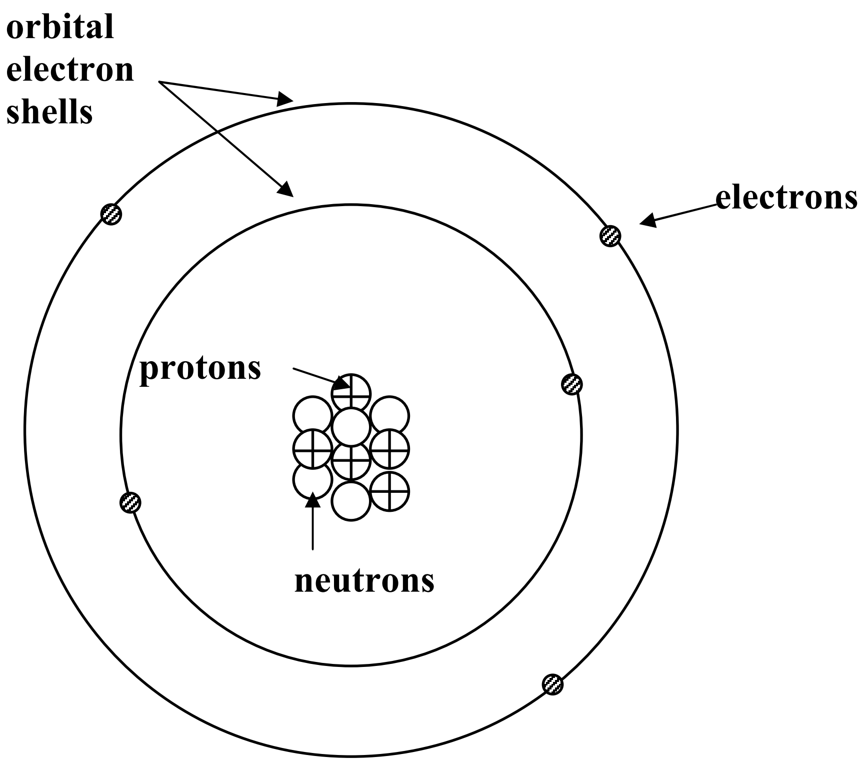
A Review of Static Electricity

Forces related to electrical charges can be explained using the model of the atom developed by Neils Bohr in the early part of the 20th century.

Consider the following model of a **Boron** atom:



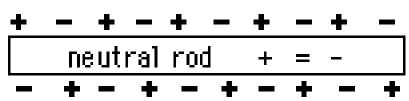
Relevant Points:

- There is a huge force of attraction between electrons and protons, but electrons repel electrons with an equally large force, as do protons with protons.
- The force of attraction between the protons in the nucleus and the fast moving electrons provides the centripetal force required to hold them in orbit around the nucleus. This electrical force is <u>billions</u> of times stronger than the external gravitational force exerted by Earth!
- Electrons have been given the name *negative* and protons *positive*.
- Atoms have the same number of protons as electrons, and are electrically neutral.
- Atoms can only lose or gain electrons to become positively or negatively charged; a charged atom is called an *ion*.
- The innermost electrons are bound tightly to the nucleus, but the outermost electrons are bound relatively loosely and can be dislodged. The force required to do this depends on the substances present.

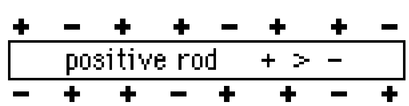
- Electrons can be transferred from one material to another, resulting in objects becoming positively and/or negatively charged. Only electrons can travel in solid objects.
- Electrons cannot be created or destroyed (called the *Law of Conservation of Charge*).
- *Insulators* are poor conductors of electricity. The outer orbit electrons are anchored fairly strongly to the nucleus of the atoms contained within these materials, leaving very few free electrons to move through.
- *Conductors* allow electrons to flow easily through them. Within the atoms of these materials, the outer orbits are so loosely held to the nucleus that no outer electron sems to belong to any particular atom. These electrons are free to roam from one atom to another as well as throughout the materials.
- *Semi-conductors* allow limited movement of a few free electrons, so some electron flow occurs. In such materials, a charge can be built up, but will disappear fairly quickly.

For any given solid object, its charge is always indicated from the point of view of a lack or an excess of electrons of a body. This is because only electrons have the ability to move within solids (protons and neutrons are locked in place as the nuclei of all atoms contained within the solid).

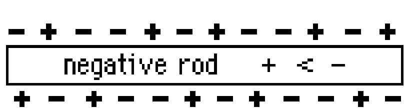
➢ **Neutral:** Every proton in the material has a balancing electron leaving no excess or lack of electrons.



➢ **Positive:** a deficiency of electrons. Foe example, when an acetate rod is rubbed with silk, electrons are displaced from the acetate to the silk. Acetate now has a lack of electrons and is positive.



➢ **Negative:** an excess of electrons. For example, when an ebonite or vinyl rod is rubbed with wool, electrons are removed from the wool and go to the rod, creating an excess of electrons in the rod to become negative.



Because electrons are attracted to protons, objects tend to be neutral, with no charge. However, a charge can be placed on an object in a number of ways:

A. *Charging by Conduction*
When two objects are in contact with each other, electrons can move directly from one material to another. For example:

- If a charged conductor touches a neutral conductor, electrons will immediately move from one to another. Electrons flow from the negative body to the positive body, or from the more negative to the less negative body, or from the less positive to the more positive body.

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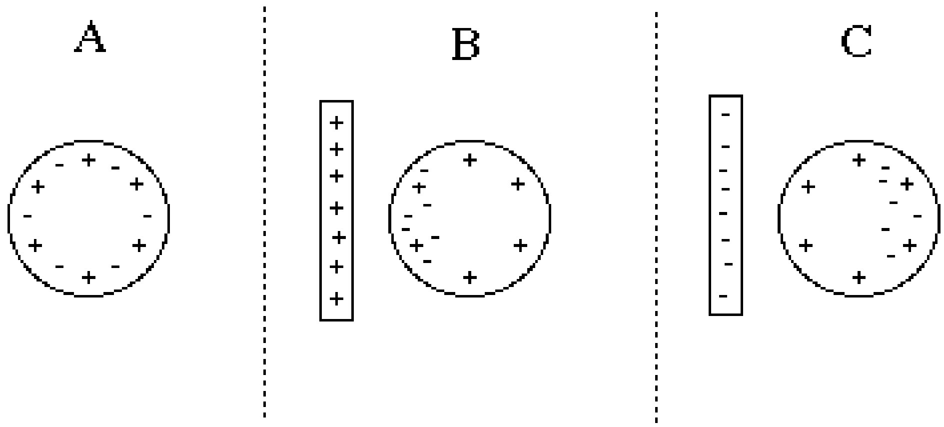
- If two insulators are rubbed together, the increased contact will cause electrons to "rub" off the material that holds electrons more loosely. These electrons are transferred to the material that holds its outer electrons more tightly, so that the latter material becomes negatively charged. Some examples:
  - rubbing **ebonite** or **vinyl** with **wool** will make both ebonite and vinyl negatively charged and the wool positively charged
  - rubbing **acetate** or **glass** with **silk** or **rayon** makes the former two materials positive and the latter two negatively charged

  An insulator can also charge a conductor in this way, so long as the electrons have no means to escape the conductor. Aircraft, for example, are often charged on the metallic surface by air rubbing the plane's aluminum skin when in flight.

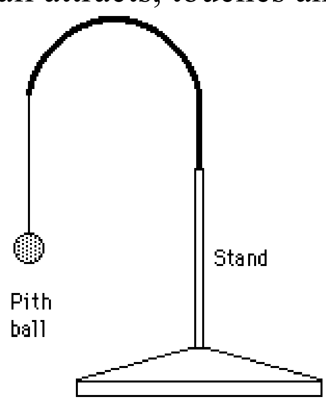
B. *Charging by Induction*
Because electrons in conductors can move easily and *because* electrons repel other electrons but attract protons, a charge brought near to a conductor, but not touching it, will cause the electrons in the conductor to move away from an external negative charge or towards a positive external charge. Note that when electrons move inside a material in this manner, so that one side becomes negative and the other side positive, we say that charge has been separated. This is what happens in a chemical cell (mistakenly called a battery).

Examine the three diagrams below. Note that in **B** and **C**, the presence of a charged rod causes a temporary induced charge. In particular, even though the ball remains neutrally charged (i.e. no net gain or loss of electrons), the near end of the ball is always charged oppositely to the charged rod, resulting in attraction. It is this induced charge which causes charged objects to attract neutral objects.



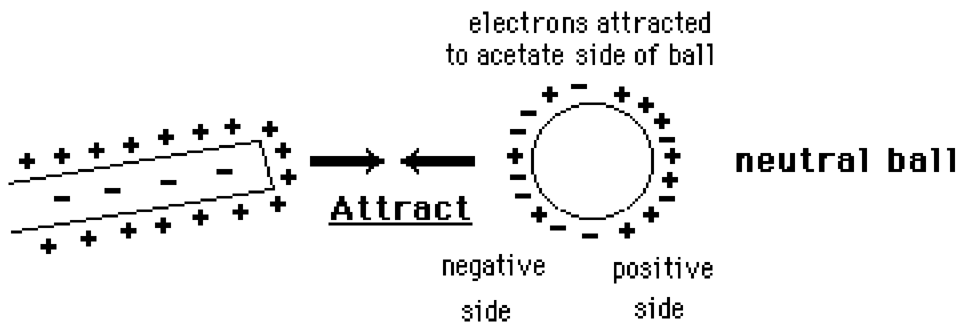
An electroscope is a simple device that detects static charges. Importantly, an electroscope can show the effects of charging by both conduction and induction.

Examine the pith ball electroscope below. When a charged rod is brought near the neutral pith ball, the ball attracts, touches and then repels.

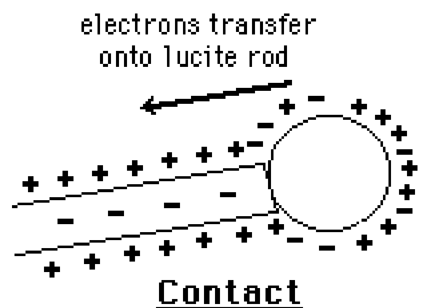


As already shown, any charge attracts a neutral object. Consider the diagrams below:

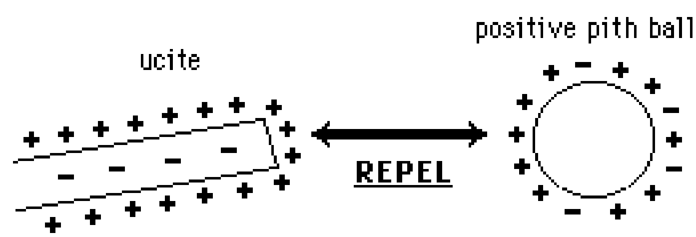
- In this case a positive charged acetate rod attracts the pith ball.



- The pith ball touches the acetate rod...



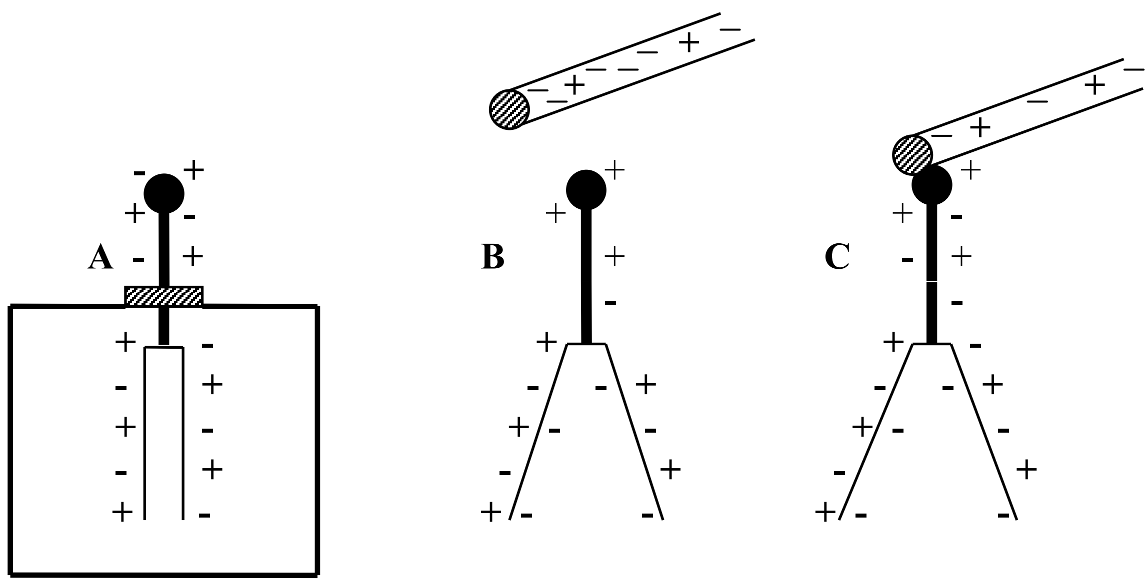
- ...and the now positively charged ball repels the positive acetate rod.



This phenomenon demonstrates that *like charges repel*, *unlike charges attract*, and *either charge attracts neutral*.

What follows is a drawing of a leaf electroscope being charged:

- In diagram **A**, the electroscope is 'neutral'; the number of positive and negative charges is equal, and the negative charges are equally distributed among the positive charges.
- In diagram **B**, a negatively charged rod is brought towards the electroscope top. While the electroscope as a whole stays 'neutral', each electroscope leaf has a negative charge *induced* in it because of the movement of electrons away from the rod. The similar nature of their charges causes the leaves to begin to spread apart by *induction*.
- In diagram **C**, the rod touches the electroscope top, allowing some of its electrons to enter the electroscope, giving it a net negative charge. The electroscope leaves continue to be spread apart, this time by *conduction*.



Finally, consider grounding. A *ground* is any conductor with a large enough mass to be able to easily give up or receive electrons without that action much affecting the overall neutral charge of the ground. Any object with a huge reservoir of charged particles compared with the charged object in question can act as a ground (e.g. you). As you might expect, the Earth is the largest and most effective ground.